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An example of a virtual reality learning environment

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Abstract
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Virtual Reality Application Center, Instructional Technology Center, computer simulation, meteorology, three dimensional computer graphics, tornadoes, visualization, learning environment, virtual tornadic supercell, virtual reality

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AN EXAMPLE OF A VIRTUAL REALITY LEARNING ENVIRONMENT

BY WILLIAM A. GALLUS JR., DOUGLAS N. YARGER, CAROLINA CRUZ-NEIRA, AND REX HEER

Science courses such as those offered in meteorology often force students to visualize complex in-- teractions of different forces and processes. Traditionally, two-dimensional or simple three-dimensional graphics have been used to assist in understanding the concepts. Although these visual aids can help a students grasp some challenging concepts, they may fail in particularly complicated situations where significant three-dimensional variability is present.

A severe, rotating thunderstorm is a particularly difficult meteorological phenomenon to explain and visualize. Yet the subject is one of the most popular among students due to the significant attention severe weather receives in the popular media. An understanding of this type of complex atmospheric event requires adequate three-dimensional visualization of atmospheric processes. Virtual reality (VR) provides a diversified medium for visually, aurally, and interactively experiencing such a phenomena (e.g., Cruz-Neira 1998). Through the use of VR, a learning environment can be created where users perceive three-dimensional structures within a tornadic thunderstorm.

Using photographic, computer graphical and experimental data, a pilot model of a tornadic supercell thunderstorm was created in a virtual environment at Iowa State University. The tornadic thunderstorm was designed to be visually realistic and to facilitate improved student understanding of both the atmospheric dynamics and the visual characteristics of such a storm. One goal of the project was to give students the virtual experience of being in the field, experiencing the dramatic features of typical tornadic supercells, and stimulating them to explore and ask questions in this learning environment. Although an initial attempt was made to use numerical simulation output in the virtual environment, such output at present is of insufficient quality (numerical simulations generally do not reproduce all features of the tornadic supercell equally well at a specific time) to achieve the desired visual realism. Because of this, an artist was part of the development team, and a one-time snapshot of the storm, representing the steady state mature phase was created.

As simulations of tornadic thunderstorms improve, the model output could be processed using automated artistic techniques to achieve visual realism, and a time-evolving virtual storm could be produced.

One design challenge in constructing this virtual storm was creating flexibility in the complexity of the tool's applications to allow its use in both introductory courses taken by hundreds of nonmajors and in smaller upper-level major meteorology courses as well. At this development stage two separate types of virtual reality tools allow users to move freely around the system. In this way, they can see the dramatic changes in appearance caused by the normally asymmetric distribution of precipitation and the variation in size of important storm-scale elements such as the wall cloud, anvil cloud, overshooting top, and the tornado. The most dramatic version is one created for a fully immersive environment, the C6 CAVE, where all six sides of a cube are projection screens, with the user housed within, wearing 3D glasses. To increase dissemination, another version was created for use on PCs, allowing full navigation in a 2D environment. One view of that virtual storm from rather far away can be seen in Fig. 1. This screen capture was taken in flight mode from a low elevation. An extensive rain shield is associated with the storm in much of the right half of the image, while a narrower curtain of rain representative of the radar hook echo is visible to the left of the road.

Because the storm is proportioned correctly to the scale of a typical supercellular thunderstorm (so that the activity domain spans roughly 100 × 100 miles), students can spend significant amounts of time exploring both the larger-scale storm features, such as anvil cloud cover and rain region, and the smaller-scale features such as the tornado itself. Fig-

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ure 2 shows what students might see if they fly (at very low elevation) or drive from the position where Fig. 1 was viewed to a position much closer to the tornado and near the main updraft. Blowing dust partially obscures the view of the tornado from this position.

In the current virtual storm, students are only exposed to visual information. Thus, the amount of exploration that they can undertake is somewhat limited. As part of a laboratory exercise in a junior meteorology course, the activity was used as a constructivist tool. A successful constructivist tool possesses complexity and authenticity that maintains the structure of the material to be learned and inherently provides reasons for knowing (Yarger et al. 1998). Students were assigned to groups of two or three and asked the following questions:

1. Sketch out a 2D graphic that would show the distribution of cloud cover and precipitation in the storm if viewed from directly above.
2. Is the rain area symmetric about the tornado?
3. Hypothesize some reasons for your answer in #2.
4. Does the cloud cover seem to extend the same distance from the tornado in all directions?
5. Explain some reasons why your answer in #4 might be the case.
6. If you knew that mid- and upper-level winds were from the northwest for this event, from what direction would you want to drive into the storm if you wanted to see the tornado far away without getting wet?

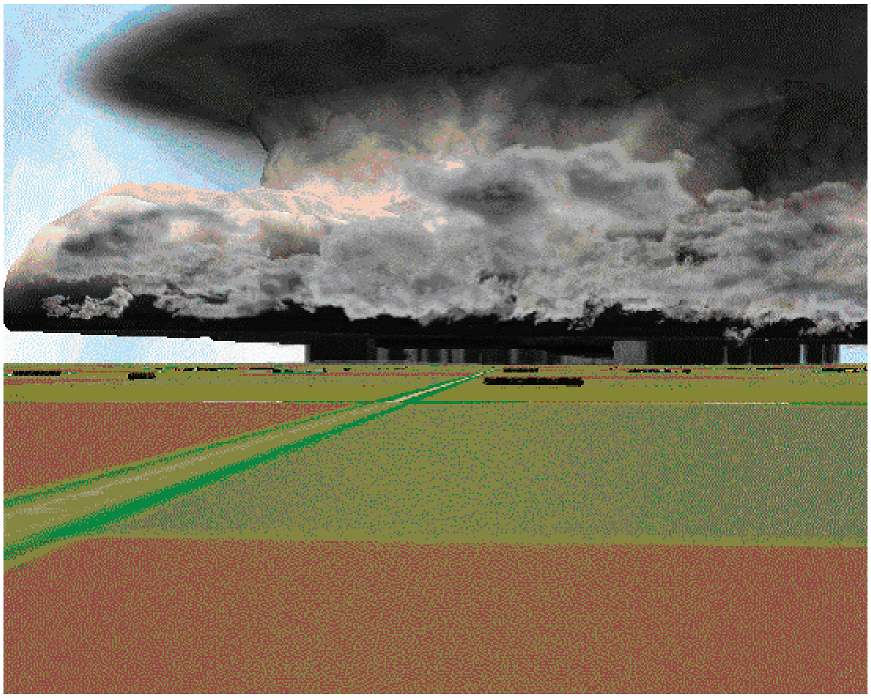

Fig. 1. View of the PC version of the virtual tornadic supercell looking west from a point roughly 25 miles away from the tornado.

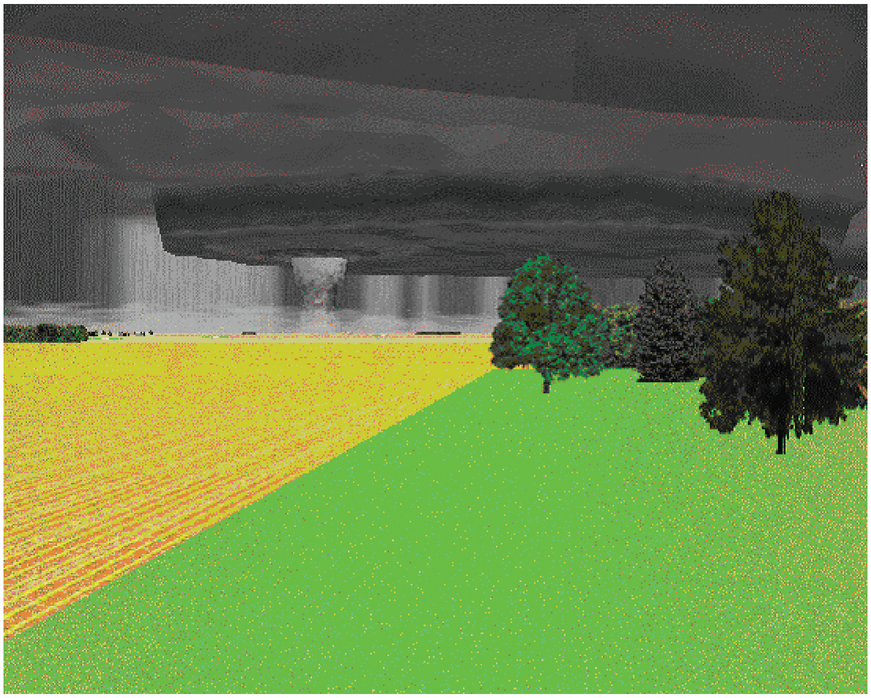

Fig. 2. View of the tornado within the virtual storm, looking west from about 5 miles away from the tornado.

Thunderstorm dynamics and structure were not yet addressed in course lectures. Students engaged in lively discussions within their groups as they tried to answer the questions (more information available online at www.pals.iastate.edu/mteor). Most students ended up frequently navigating back and forth from far and near distances as they tested their answers to the questions.

Work to expand the usefulness of this learning environment is ongoing. Although audio effects and storm propagation (but without temporal evolution) are being added, along with improved visual depiction of some storm features, the most valuable changes being made are the abilities to overlay data and permit data probing. We expect that data overlay would benefit nonmajors and plan to use the activity in the large-lecture (400 student) introductory meteorology courses at Iowa State University. Learning environments like this are essential in such courses, which often fulfill general education requirements and may be the only exposure to the scientific method that some students will ever get. Data probe capabilities might be used by upper-level meteorology majors. Questions similar to those asked above would serve as strong motivation for these students to design measurement strategies. For example, if students were asked to find the coldest surface temperatures in the region, they might first decide to take samples from a variety of points experiencing different weather conditions. Next, if they find somewhat cooler temperatures in a region of rain, they would want to increase sampling density in the rainy regions. They might then be asked to offer explanations for these cold temperatures.

Initial feedback from the prototype version has been favorable. Future versions of the activity will make use of improved computational technology, allowing broad dissemination through digital libraries.

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REFERENCES

Cruz-Neira, C., 1998: Making virtual reality useful: Immersive interactive applications. *J. Future Gen. Comput. Syst.,* **14,** 147–156.

Yarger D. N., J. P. Boysen, R. Thomas, and M. R. Marlino, 1998: Developing and implementing a constructivist learning environment: Translating theory into practice. Preprints, *10th World Conf. on Educational Multimedia and Hypermedia and Conference on Educational Telecommunications*, Charlottesville, VA, Assoc. for the Advance. of Computing in Edu., 2116–2119.